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DISPERSAL OF JUVENILE AND IMMATURE BONELLI'S EAGLES IN NORTHEASTERN SPAIN

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ABSTRACT.—Between 1986–93, we wing tagged and banded 122 Bonelli's Eagles (*Hieraaetus fasciatus*) in northeastern Spain to analyze their dispersal before recruitment to the breeding population. By 1998, we had obtained 18 band returns and 42 incidental observations of juvenile and immature eagles ranging in age from 1–3 yr. These eagles were recorded from 1–1020 km from their nests with a geometric mean distance (95% C.I.) of 101 km (72–153). Up to 57% of the birds remained within a radius of 100 km of their nests, whereas 33% were found beyond 200 km. Short-distance dispersers were found mainly in northeastern Spain in central Catalonia (<200 km), while long-distance dispersers (>200 km) were found in central and southeastern Spain. No significant difference in dispersal distance was found between males (101 km, 40–273, $N = 15$) and females (189 km, 86–419, $N = 11$), but males were mostly recorded at shorter distances. Dispersal distances of juveniles (114 km, 68–193, $N = 43$) and immatures (77 km, 44–135, $N = 16$) also did not differ significantly, but immatures were mostly recorded at shorter distances. No significant difference was found between sighting (82 km, 54–137) and band recovery (167 km, 87–323) distances, but the proportion of band recoveries to sightings was lower for short- than for long-distance dispersers, and it increased with distance. The recording rate declined sharply at the end of the first year of life, suggesting high mortality during this period. The main causes of death were electrocution and human persecution. Most long-distance dispersers were reported dead, suggesting that long-distance movements entailed some mortality costs.

KEY WORDS: *Bonelli's Eagle*; Hieraaetus fasciatus; *subadult dispersal*; *Catalonia.*

Dispersión de juveniles de águila perdicera en Cataluña

RESUMEN.—Describimos el patrón de recuperaciones y observaciones de 122 Águilas Perdiceras (*Hieraaetus fasciatus*) equipadas con marcas alares y anillas en Cataluña, España entre 1986–93 con objeto de obtener información sobre sus movimientos antes de que sean reclutadas en territorios de cría. Hasta el final de 1998, se obtuvieron 18 recuperaciones de anillas y 42 observaciones de águilas no adultas. Las águilas se registraron entre 1 y 1020 km de sus respectivos nidos. La media geométrica de la distancia de registro (95% I.C.) fue de 101 km (72–153). Un 57% de las águilas permanecieron dentro de un radio de 100 km del lugar de nacimiento, pero un 33% se alejó más allá de 200 km. La zona central de Cataluña fue la principal área de acogida para las aves que se dispersaron a corta distancia (<200 km), mientras que las aves que efectuaron largos desplazamientos (>200 km) se dirigieron principalmente al centro y al sureste de España. No se encontraron diferencias significativas en la distancia de dispersión entre machos (101 km, 40–273, $N = 15$) y hembras (189 km, 86–419, $N = 11$), aunque una elevada proporción de machos se encontraron cercanos a las áreas de nidificación. La distancia recorrida no difirió entre juveniles (114 km, 68–193, $N = 43$) e inmaduros (77 km, 44–135, $N = 16$), pero estos últimos se registraron más frecuentemente a cortas distancias de las áreas de nidificación. No se encontraron diferencias significativas en la distancia según fueran observaciones (82 km, 54–137) o recuperaciones (167 km, 87–323), pero la proporción de recuperaciones en relación a las observaciones fue menor para cortas que para largas distancias de dispersión e incrementó con la distancia. La tasa global de recuperaciones y observaciones disminuyó acusadamente al final del primer año de vida, sugiriendo una elevada mortalidad durante este período. Las causas principales de mortalidad fueron la electrocución y la persecución. Los ejemplares dispersados a larga distancia fueron más frecuentemente registrados muertos que vivos, sugiriendo que los movimientos a larga distancia conllevan costes de mortalidad.

[Traducción de Autores]

In many large birds of prey, juveniles show nomadic behavior soon after becoming independent (González et al. 1989, Cugnasse and Cramm 1990). These juvenile dispersal movements, as they are called, may lead young birds to settle in juvenile dispersal areas, which are seldom occupied by

breeding conspecifics (Ferrer 1993a, 1993b, Mañosa et al. 1998). In most cases, these nomadic birds are philopatric and return to breed near their natal areas (Newton 1979). Long-distance juvenile dispersal has been associated with individuals in the best of health (Ferrer 1992, 1993b, Walls et al. 1999). It allows them to explore and settle in new optimal and unoccupied areas (Horn 1983, Nilsson 1989). However, it may also entail several costs in terms of increased mortality or reduced lifetime reproductive success (Belichon et al. 1996), which is associated with suboptimal areas.

Populations of Bonelli's Eagles (*Hieraaetus fasciatus*) are declining in most parts of Europe (Rocamora 1994), mainly as a result of high mortality (Real and Mañosa 1997). A sharp decline in the population in northern Spain has been partially attributed to unbalanced patterns of dispersal that may favor more southern populations (Real and Mañosa 1997). Although adults are sedentary (Cramp and Simmons 1980), juvenile and immature Bonelli's Eagles (1–3 yr old) show a wandering behavior (Cramp and Simmons 1980, Cugnasse and Cramm 1990, Mañosa et al. 1998), which has been poorly described. The aim of our study was to obtain data on the location of nonbreeding areas used by juvenile and immature Bonelli's Eagles hatched in northeastern Spain. We also collected information on the average distances traveled and the proportion of individuals involved in these movements. Finally, we discuss the implications of these movements in terms of the life history, population status, and conservation of Bonelli's Eagles.

METHODS

We conducted a wing tagging and banding project in northeastern Spain in Catalonia involving 36 pairs and 83 breeding attempts of Bonelli's Eagles from 1986–93. Every nestling between 40–55 d of age was marked with a 6-g metal ring on one leg, a 6-g, 3-digit PVC ring on the other leg, and plastic wing tags (Kochert et al. 1983) on each wing. The tag on the right wing identified the bird's area of origin and the color of the left tag denoted the year of tagging. Wing tags measured 6.7 × 13.5 mm when folded and weighed 11 g including rivets. We wrapped the wing tags around the humerus between the tertiaries and scapulars and secured them with two pop rivets and glue. Wing-tag components were supplied by Saflag (Safety Flag Co. of America, Pawtucket, RI U.S.A.) between 1986–87, and by TXN-18 (Cooley Inc., Pawtucket, RI U.S.A.) between 1988–93. The age and sex of every nestling was determined at the time of banding following Mañosa et al.(1995).

We compiled data on movements of tagged eagles from band recoveries of birds found dead or injured and from incidental sightings of tagged birds. We requested information on sightings of tagged eagles in Spain, France, Portugal, Italy, and Morocco by advertising in journals and newsletters of the main ornithological and conservation associations of southern and central Europe and northern Africa. We did not consider successive sightings of the same tagged bird in a given area. Since our study focused on dispersal movements of juvenile and immature eagles and not on natal dispersal, we analyzed only sightings and band recoveries involving nonbreeding birds <3 yr old. According to published information about the postfledging period of Bonelli's Eagle (Real et al. 1998), the birds sighted or recovered before 100 days after fledging and within a radius of 8 km from the nest were not dispersed, and were not considered.

We computed distances traveled and compass directions from natal nests, if known, or from the geometric center of marking areas if the exact identity of birds was unknown. In this case, however, compass direction of the movement was only reported for birds observed outside the circle centered on the geometric center of the marking area and encompassing all the nests where young eagles were tagged.

Bird ages were all computed from 31 May (age 0) of the hatching year, the approximate average fledging date for the study population (Real 1991). We established two age categories: juvenile (<366 d of age) and immature (366–1095 d of age).

As dispersal distances showed a skewed distribution, results are given as geometric mean distances with 95% C.I We used 2-tailed *t*-tests (unless otherwise stated) to compare log-transformed dispersal distances between sightings and recoveries, between males and females, and between juvenile and immature categories. We used Fisher exact probability tests to compare percentages. We conducted standard statistical analyses with the SPSS package for Windows (SPSS-Inc. 1990) and computed circular statistics following Zar (1984).

RESULTS

After accounting for tag loss in nests and mortality during the nestling period, we estimated that 122 tagged nestlings successfully fledged from nests. At least four of them died during the dependency period (3.3% of tagged birds). One was killed by an Eagle Owl (*Bubo bubo*), one starved, and two were electrocuted. We recorded 18 band recoveries (15%) and 42 sightings (35%) of tagged eagles between 1986–98. Most of these occurred in the first year after fledging and declined thereafter (Fig. 1).

Juvenile and immature eagles dispersed to 1–1020 km from natal areas (Fig. 2). Because these distances showed a bimodal distribution (Fig. 3), we classed the eagles as either short-distance (<200 km) or long-distance dispersers (>200 km). Some juvenile Bonelli's Eagles moved >500 km from their natal areas within 1 mo of fledging (Fig. 2). The geometric mean dispersal distance (95%

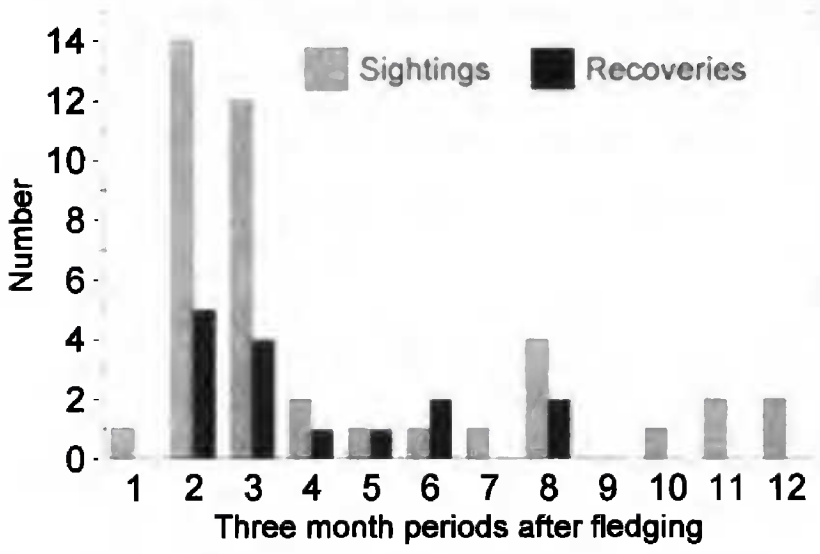


Figure 1. Number of sightings and band returns of juvenile and immature Bonelli's Eagles in relation to time after fledging.

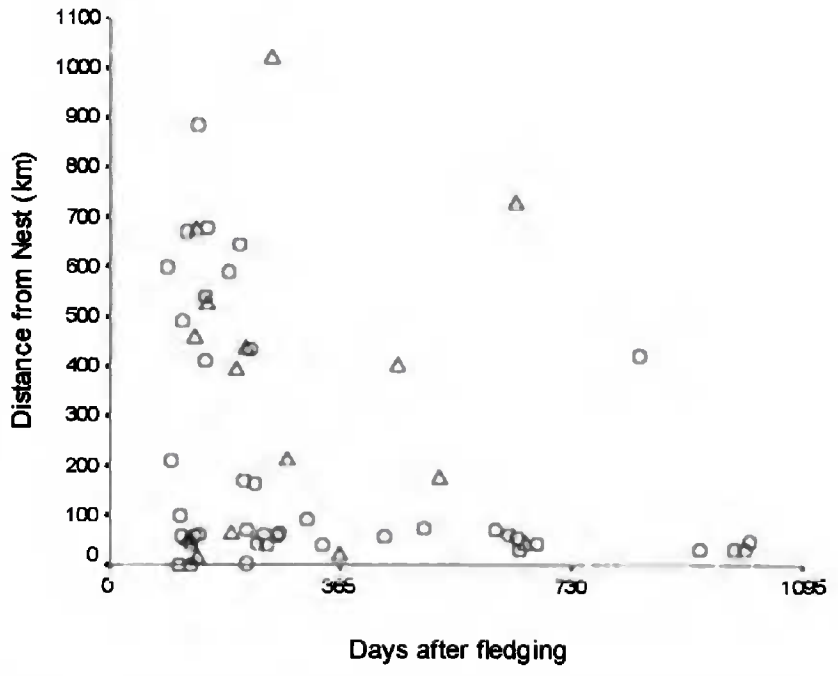


Figure 2. Dispersal distances of juvenile and immature Bonelli's Eagles after fledging. Circles represent sightings and triangles represent band recoveries.

C.I.) was 101 km (72–153, $N = 60$), with a median of 70 km. Although most birds (57%) were reported within 100 km of their natal sites, 33% went farther than 200 km (Fig. 3). The proportion of long-distance dispersers was similar in both sexes (5 of 11 females vs. 7 of 15 males), and the distance traveled by females (189 km, 86–419, $N = 11$) was not significantly different from that traveled by males (101 km, 40–273, $N = 15$; $t_{24} = -0.98$, $P = 0.34$). However, a higher proportion of males concentrated at shorter distances (Fig. 4a). The distance traveled did not differ between juvenile (114 km, 68–193, $N = 43$) and immature eagles (77 km, 44–135, $N = 16$; $t_{57} = 0.99$, $P = 0.33$); but, while the number of juveniles increased with distance, immatures showed the reversed trend (Fig. 4b).

The average azimuth to which eagles traveled was 258 ± 59°E, $N = 33$). Most short-distance dispersals were recorded in central Catalonia, followed by the Ebre delta and the Aiguamolls de l'Empordà (Fig. 5a, b). Long-distance dispersers were mainly reported in central (Madrid, Toledo, and Extremadura) and southeastern (Alicante, Murcia, Albacete, and Eastern Andalusia) Spain, with fewer reports in northern Spain and France (Fig. 6). The distance at which sightings (82 km, 54–137) and band recoveries (167 km, 87–323) were reported did not vary significantly ($t_{59} = 1.66$, $P = 0.10$), whereas the proportion of band recoveries to sightings was lower for short-distance dispersers (9 vs. 31) than for long-distance dispersers (9 vs. 11) (one-tailed Fisher exact probability test = 0.07), and increased with distance, as did the absolute number of recoveries (Fig. 4c).

Of the 18 banded birds found dead, 10 (55%) were electrocuted, 4 (22%) were shot, trapped or poisoned, 1 (6%) starved, and the cause of death for the remaining 3 (17%) was unknown. For short-distance dispersers, 5 (72%) were electrocuted, 1 (14%) was shot, and 1 (14%) starved. For long-distance dispersers, 5 (63%) were electrocuted and 3 (37%) were killed by people.

DISCUSSION

A significant fraction of young Bonelli's Eagles produced in northeastern Spain travel long distances. Although banding and wing tagging are more likely to provide information on populated areas (Kochert et al. 1983, Young and Kochert 1987, Francis and Cooke 1993), we believe that the

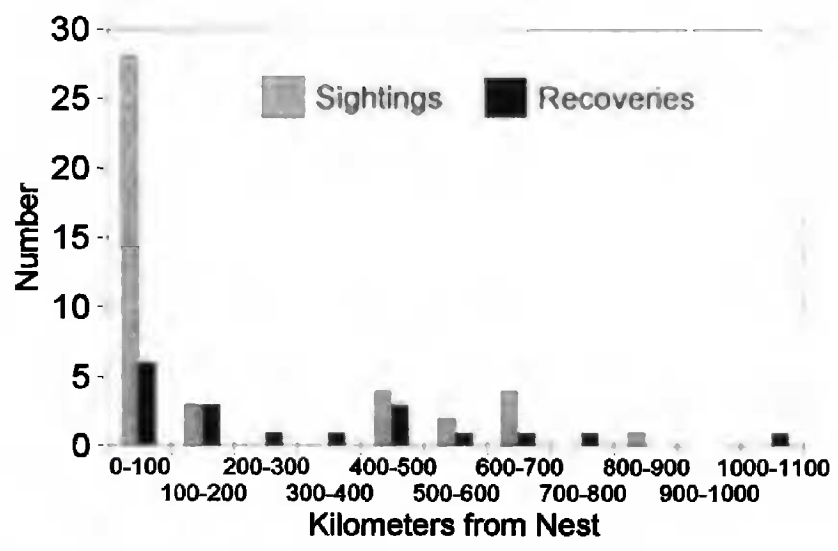
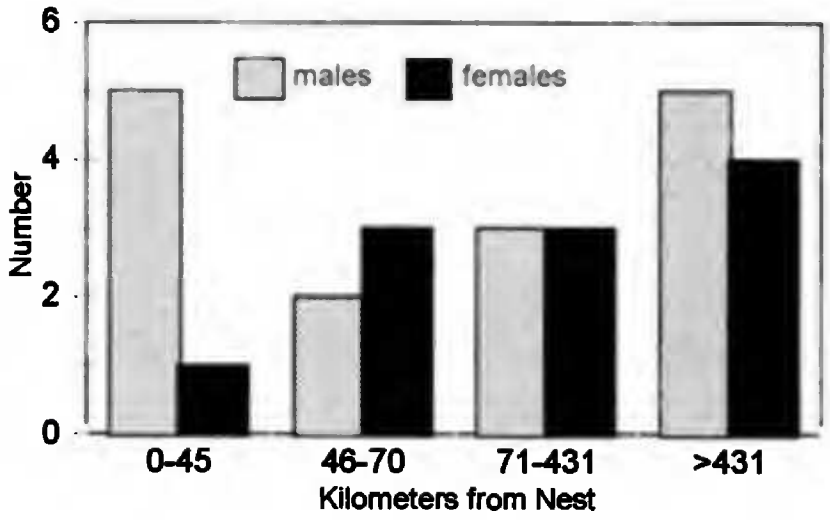
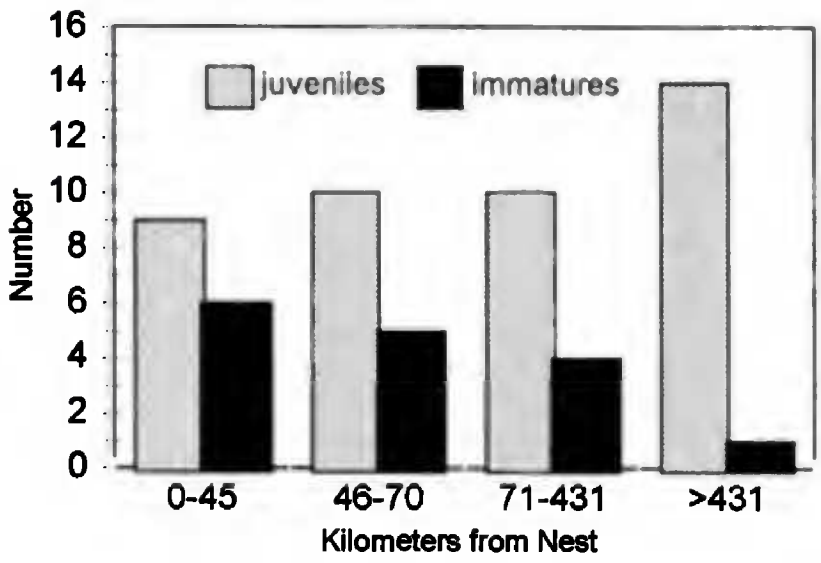


Figure 3. Distribution of the number of sightings and band recoveries of juvenile and immature Bonelli's Eagles according to distance (km) traveled.





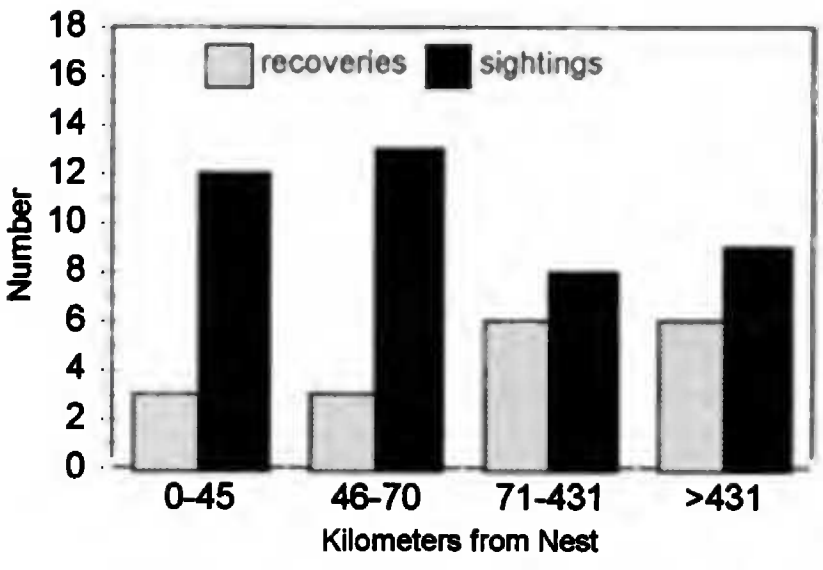


Figure 4. Distribution of distance traveled by (top) male and female Bonelli's Eagles, (middle) juvenile and immature Bonelli's Eagles, and (bottom) band recoveries and sightings. Intervals are 25% percentiles of the global distance distribution.

effect of such bias on our results was low. The areas with high observation rates (northeastern, central, and southeastern Spain) are not among the most frequently visited by ornithologists and birdwatchers. Moreover, the main dispersal areas we have identified agree with those recently-identified by conventional or satellite radio telemetry, as well as with areas where concentrations of juvenile and immature Bonelli's Eagles have been previously reported (Arroyo and Garza 1996, Cheylan and Marmasse 1998, Mañosa et al. 1998).

Male and female eagles showed different dispersal patterns. Although both genders moved long distances, male Bonelli's Eagles remained near their natal areas more often as is typical of other species of raptors (Greenwood et al. 1979, Newton and Mearns 1988, Ferrer 1993a, Walls and Kenward 1995). The opposite trend shown by juvenile and immature eagles may indicate that Bonelli's Eagles return to their natal areas as they grow older (González et al. 1989, Walls and Kenward 1994) or that long-distance dispersers suffer high mortality (Belichon et al. 1996). Higher mortality associated with dispersal could have accounted for the marked decline in the number of sightings and band recoveries with age. Our data suggest that power line casualties and illegal persecution by people remain chief causes of mortality for juvenile and immature Bonelli's Eagles.

The fact that relative and absolute numbers of recoveries (dead eagles) increased with distance from natal areas indicated that long-distance movements entailed a cost for eagle survival. Moreover, all the eagles that had moved to northern and Atlantic France, far from the usual distribution range of the species, were reported dead or in poor condition.

Juvenile Bonelli's Eagles that fledge in northeastern Spain undertake long-distance movements more often than eagles in France (Cheylan et al. 1996), and may thus experience additional mortality (Belichon et al. 1996). The population of Bonelli's Eagles in northeastern Spain is at the edge of the distribution range of the species, and might thus be particularly exposed to the negative consequences of dispersal (Gadgil 1971, Walters et al. 1999). Since a large fraction of the Bonelli's Eagles produced in northeastern Spain move to close or distant dispersal areas, their conservation should rely on the effective management of these areas. This includes the reduction of power line mortality and illegal persecution, and management to main-

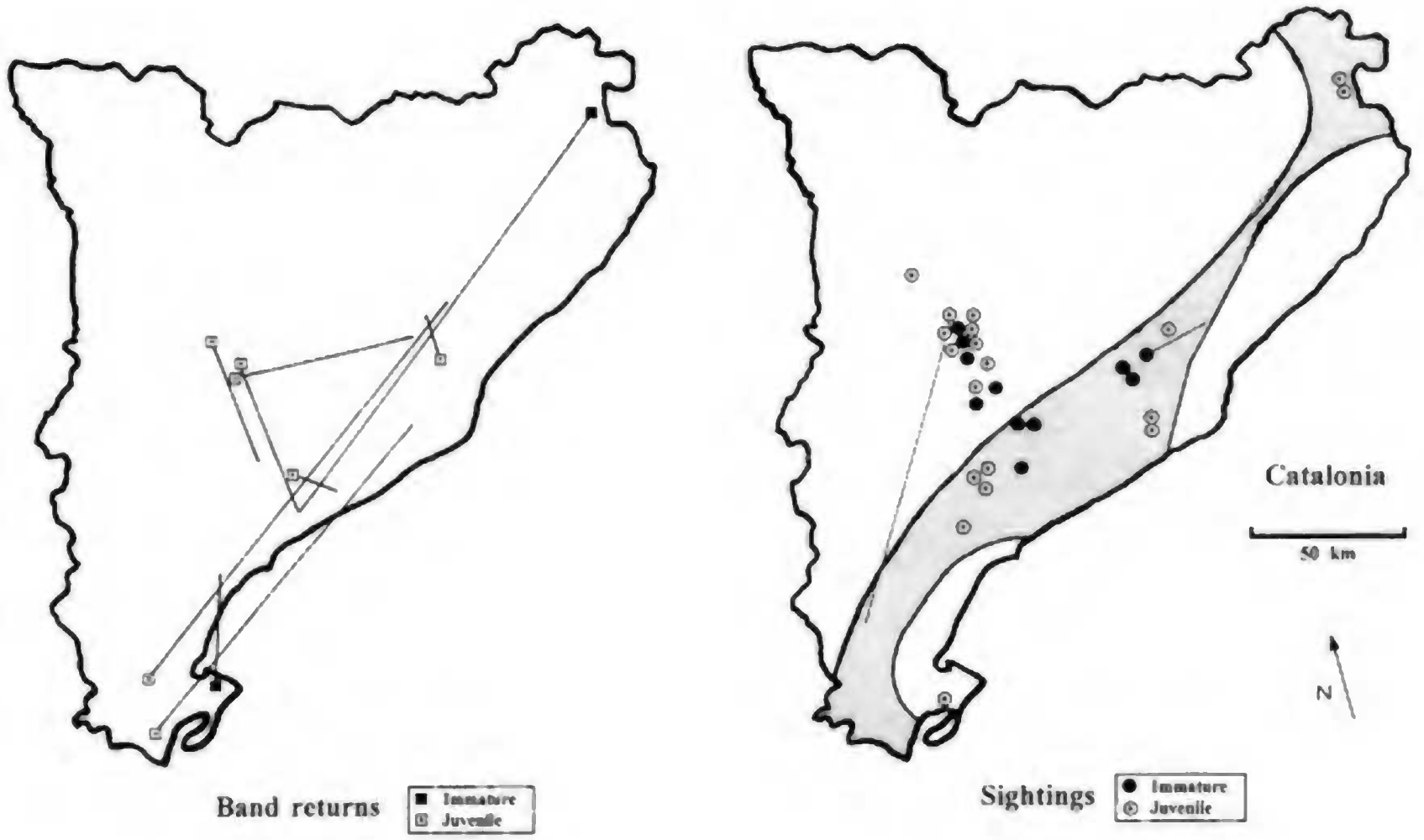


Figure 5. Maps of the study area showing short-distance (<200 km) records of juvenile and immature Bonelli's Eagles. The shaded area shows the tagging region. Lines join known natal sites and recovery sites.

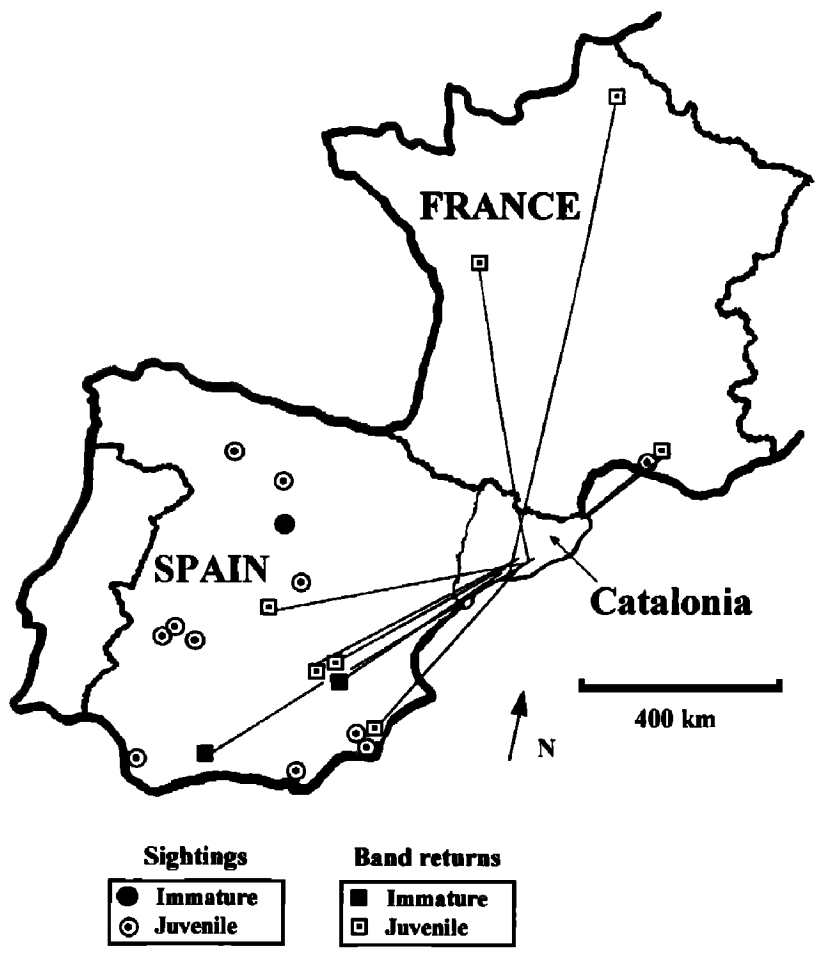


Figure 6. Map of long-distance (>200 km) band recovery and sightings of juvenile and immature Bonelli's Eagles dispersing from northeastern Spain. Lines join known natal sites and recovery sites.

tain sufficient prey availability (Bustamante et al. 1997, Ferrer and Harte 1997, Mañosa et al. 1998). These measures should be undertaken both in northeastern Spain and in distant dispersal areas in southern and central Spain.

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